J. Dairy Sci. 94:4046–4056
doi:10.3168/jds.2011-4277

Effects of supplementation with yeast culture and enzymatically hydrolyzed yeast on performance of early lactation dairy cattle

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ABSTRACT

One hundred fifty multiparous cows were balanced to 1 of 3 treatments (2 pens/trt) according to previous lactation 305-d mature equivalent yield to evaluate supplementation with yeast culture (YC; A-Max, Vi-COR, Mason, IA) and YC plus enzymatically hydrolyzed yeast (YC+EHY; Celmanax, Vi-COR) on production performance in dairy cattle. Cows entered pens at calving and remained through 14 wk postpartum. Treatment assignment to pens was random throughout the barn. Pens were identical in layout and each contained an exit alley to eliminate feed and animal mixing. The 3 treatments were control: nonsupplemented; YC: control diet with YC (56 g/d); and YC+EHY: control diet plus YC and EHY (28 g/d). Mean pen dry matter intake was similar across treatments. Cows supplemented with YC and YC+EHY produced more milk, fat-corrected milk, and energy-corrected milk than control cows (1.4 and 1.6, 1.6 and 1.8, 1.7 and 1.9 kg, respectively). Treatments YC and YC+EHY did not differ. Milk fat and lactose percentages were not affected by treatment. Milk protein percentage was higher for cows supplemented with YC+EHY than for those on YC and control treatments (2.98, 2.93, and 2.91%, respectively) with control and YC-supplemented cows not being different from each other. Differences in fat and protein yields were primarily reflective of milk yield. Treatment had no effect on milk urea nitrogen. No differences in the incidence of metabolic health were observed; however, cases of clinical mastitis for YC+EHY were less than half those for control and YC during wk 8 to 14 on trial. Somatic cell count was higher for cows fed control and YC diets compared with YC+EHY, primarily during wk 8 to 14 on trial. Supplementation of early lactation cows with YC improved milk production performance; furthermore, EHY supplementation improved milk protein percentage and mammary gland health.

Key words: yeast culture, enzymatically hydrolyzed yeast, milk performance, somatic cell

INTRODUCTION

Yeast culture supplementation in dairy rations is efficacious and has been practiced commercially for several years (Piva et al., 1993; Swartz et al., 1994; Newbold et al., 1995). A recent meta-analysis (Desnoyers et al., 2009) of 157 experiments demonstrated that yeast supplementation increased feed intake, milk production, rumen pH, rumen VFA, and organic matter digestibility. In addition, the effects of yeast were enhanced when animals consumed diets with a higher proportion of concentrate. Their results also suggested that yeast supplementation limited the decrease in rumen pH typically associated with increased VFA concentration and decreased lactic acid, suggesting an enhanced buffering capacity. Positive responses to yeast may therefore be to mitigate the negative effects of feeding high-concentrate diets (Desnoyers et al., 2009).

Sub-therapeutic use of antibiotics has demonstrated many benefits in animal production (Ferket, 2003). Most economical benefits are associated with increased feed conversion, faster rate of growth, and reduced mortality. Antibiotics generally work by limiting detrimental microorganisms as well as growth and colonization of nonpathogenic bacteria. This in turn reduces weight and length of intestines, metabolic demands for the gastrointestinal system, and overstimulation of the host immune system, all of which draw nutrients away from optimal performance (Visek, 1978; Klasing, 1988; Ferket, 1991). The concern associated with resistant strain development through antibiotic use has generated strong debate and objections to sub-therapeutic uses of antibiotic for promoting growth. Whether justified or not (Gustafson and Bowen, 1997), alternatives to antibiotics must be investigated.

Mannan oligosaccharide (**MOS**), a yeast cell wall component, can act as a high-affinity ligand offering competitive binding site options for gram-negative bacteria, which possess mannose-specific type-1 fimbriae (Ofek et al., 1977). The immediate benefits are associated with pathogen removal from the digestive

Received February 16, 2011.
Accepted April 17, 2011.
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system without attachment and colonization. This phenomenon may elicit significant antigenic responses, thus enhancing humoral immunity against specific pathogens through presentation of the attenuated antigens to immune cells (Ballou, 1970; Spring et al., 2000; Ferket, 2003). In addition, this process may suppress the proinflammatory immune response, which is detrimental to production performance (Ferket, 2002). Another predominant yeast cell wall component, β-1,3/1,6-glucan (β-glucan), has been shown to exhibit immunomodulatory effects when used as a supplement in aquatic (Dalmo and Bogwald, 2008), swine (Eicher et al., 2006; Li et al., 2006), and avian (Lowry et al., 2005; Chae et al., 2006) diets.

Few studies have investigated the use of yeast cell wall components on immune function in dairy cattle. Seymour et al. (1995) reported decreased incidence of elevated body temperatures in calves when 1% brewer's yeast was supplemented to a calf starter. Franklin et al. (2005) supplemented dry cows with MOS and observed enhancement of humoral immune response of cows to rotavirus and a tendency for enhanced transfer of rotavirus antibodies to calves. Supplementation of MOS in milk replacer improved fecal scores and reduced scours in calves to the same extent as antibiotics (Heinrichs et al., 2003). The therapeutic use of β-glucans infused into infected quarters of cows showed no effect on chronic subclinical *Staphylococcus aureus* mastitis; however, the proportion of milk lymphocytes tended to increase postinfusion (Waller et al., 2003). No studies have been reported to evaluate the effect of yeast culture and yeast culture plus additional yeast cell wall preparations on production performance and the incidence of postpartum disease. This study was conducted to evaluate supplementation with yeast culture (**YC**) and yeast culture with enzymatically hydrolyzed yeast (**YC+EHY**) on production performance and health in dairy cattle.

MATERIALS AND METHODS

Animals, Diets, and Experimental Design

One hundred fifty multiparous cows were balanced to 1 of 6 treatment pens (experimental unit) according to previous lactation 305-d mature equivalent yield. Cows were housed in a freestall barn that contained 6 pens (70 stalls/pen), 3 on each side of a 6-row barn. Cows entered the groups at calving and remained through 14 wk postpartum. Treatments were randomly assigned to each pen per side of barn. Pens were identical in layout and each pen contained an exit alley such that cows from adjacent pens would not interfere with or have access to another pen's treatment feed when moved for milking. Beds were sand-based, and water and feed space accessibility was equal in all pens.

The 3 treatments in this study were as follows: (1) control: fresh cow diet; (2) yeast culture (**YC**): control diet with the inclusion of A-Max Yeast Culture Concentrate (Vi-COR, Mason City, IA) at 56 g/cow per day; and (3) yeast culture + enzymatically hydrolyzed yeast (**YC+EHY**): control diet with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

The basal diets were formulated for requirements of a lactating cow at 50 DIM, producing 45 kg of 3.5% FCM milk (NRC, 2001); ingredient and nutrient composition of the control diet are shown in Tables 1 and 2. As cows were assigned to each pen, they were housed with nontrial cows of similar DIM to accommodate a one cow-one stall environment. Trial animals were identified with treatment-specific color-coded ear tags. When the first cow entered each treatment pen, treatment diets commenced until the last treatment cow was removed.

Measurements

Milk. Cows were milked twice daily (0400 and 1600 h) in a double-17 parallel milking parlor with sampling devices. Milk production was recorded daily. All daily milkings were totaled for each cow within pen on study for the same day in lactation. Total daily milks were calculated to represent mean daily milk per cow for comparative purposes. Milk samples for composition were collected and composited from each cow at p.m. and a.m. milkings (two 50:50, 30-mL aliquots) on a weekly basis. Samples were preserved, frozen, and thawed slowly after all trial cows in each group

Table 1. Ingredient composition of experimental diet

Ingredient	% DM basis
Haylage	7.7
Western alfalfa hay	5.8
Corn silage	58.6
Corn meal	10.6
Beet pulp	6.1
Soybean meal	5
Soybean (roasted)	1.8
Dairy premix[1]	4.3
Treatment premix[2]	0.1

[1]Dairy premix: 14.7% corn distillers, 5.1% corn gluten feed, 3.7% fish meal, 3.7% blood meal, 12.8% soy plus (West Central Cooperative, Ralston, IA), 16% Megalac (Arm and Hammer Nutrition Group, Princeton, NJ), 12.8% calcium carbonate, 1.9% magnesium oxide, 5.7% urea, 3.4% salt, 1.0% tallow, 7.2% sodium bicarbonate, and 12% mineral-vitamin mix.

[2]Treatment premix: control = corn meal fed at the manufacturers recommended level in 225 g/cow per day. The premix corn meal was subtracted from the diet corn meal total; yeast culture = A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day + 169 g of corn meal; and yeast culture/enzymatically hydrolyzed yeast = Celmanax (Vi-COR) at 28 g/cow per day + 197 g of corn meal.

Table 2. Chemical composition of forages and experimental diet

Nutrient	Corn silage	Hay crop silage	Hay	Diet
DM, %	32.30	37.40	92.7	52.5
CP, %	8.12	18.54	20.38	17.9
Soluble protein, % CP	69.40	61.60	54.6	33.8
NDF, %	38.28	48.80	44.96	30.5
Lignin, %	2.80	6.26	6.26	2.96
NFC, %	46.76	22.46	24.76	39.6
Fat, %	4.10	4.26	4.3	5.23
NE_L, Mcal/kg[1]	1.74	1.37	1.42	1.76
Ca, %	0.20	1.13	1.222	0.94
P, %	0.24	0.32	0.322	0.37
Mg, %	0.14	0.23	0.26	0.42
K, %	1.00	2.63	2.618	1.01
Na, %	0.00	0.02	0.0256	0.31
Zn, mg/kg	27.00	22.80	21.4	56
Cu, mg/kg	6.00	9.20	10.6	16
Mn, mg/kg	21.60	31.40	26.8	41
S, %	0.10	0.21	0.224	0.21

[1]NRC (2001).

completed each week. A weekly pen composite sample was created based on an average weighted weekly milk production per cow. Composite samples were submitted to DairyOne (Ithaca, NY) for analysis of protein, fat, lactose, and MUN by Milkoscan (Foss Electric, Hillerød, Denmark), and SCC were determined by the Fossomatic 5000 (Foss Electric). The equation used for FCM was as follows: 3.5% FCM = [0.4255 × milk (lb)] + [16.425 × (fat%/100) × milk (lb)]. Energy-corrected milk was calculated as follows: ECM = (kg of milk × 0.327) + (kg of milk fat × 12.95) + (kg of protein × 7.2) (Shirley, 2006).

DMI Estimates. Daily group intakes were recorded throughout the trial period for each treatment pen. The number of total cows represented in a given group remained constant, but did not necessarily represent cows entirely on trial. Total feed offered divided by total cows in the pen on a given day was calculated. Body weight and condition scores (Wildman et al., 1982) were taken on all animals at treatment initiation (day of calving) and termination from study.

Health. The following health indices were recorded: retained placenta (placental membranes retained for more than 24 h after calving); metritis (diagnosed by a purulent vaginal discharge); ketosis (detected by a high urine ketone content with litmus strips); displaced abomasums (detected by percussion with a stethoscope on either the left or right side of the cow). New clinical mastitis cases were detected by the following procedure. At each milking, 3 forestrip ejections of milk from each quarter were evaluated for evidence of abnormal secretions (flakes, clots, stringy, creamy, watery). If an abnormal secretion was observed, persistency was determined by stripping 6 to 8 more ejections. If the abnormal secretion persisted after 6 to 8 more ejections, the gland quarter was classified as clinical mastitis. A new clinical case on the same quarter was not declared until the infected quarter was free of abnormal secretion for at least 14 d after the declaration of normal saleable milk for that quarter.

Statistical Analysis

Statistical procedures (SAS Institute, 1999) using split-plot-in-time ANOVA for repeated measures were conducted for parameters that had a period effect; that is, milk and composition. The model was as follows: $Y_{ijk} = \mu + trt_i + pen_j\ (trt_i) + week_k + trt_i \times week_k + E_{ijk}$, where pen was the experimental unit, Y_{ijk} = dependent variable, observed value for production parameter in treatment i, in pen j for week k; μ = overall mean; trt = treatment i (i = 1 to 3); pen(trt) = random effect (error term) of the jth pen nested within the ith treatment (j = 1 to 2); week = fixed effect of week k (k = 1 to 14); trt × week = the ith treatment in the kth week; and E_{ijk} = random residual. When a period effect did not exist (i.e., BW), the model was as follows: $Y_{ij} = \mu + trt_i + pen_j\ (trt_i) + E_{ij}$, where Y_{ij} = dependent variable, treatment i, in pen j; μ = overall mean; trt = treatment i (i = 1 to 3); pen(trt) = random effect of the jth pen nested within the ith treatment (j = 1 to 2); and E_{ij} = random residual. Somatic cell data were log-transformed according to Ali and Shook (1980) for statistical analysis to obtain better statistical properties. When treatment effect was significant ($P < 0.05$), Tukey-Kramer test (Kramer, 1956) was used as a means separation procedure ($P < 0.05$). Health data were subjected to the nonparametric Wilcoxon test.

RESULTS

Production Performance

One hundred forty-two cows completed the experimental period. Reasons for cow removals are listed in Table 3. The milk yield variables milk, 3.5% FCM, and ECM were higher ($P < 0.01$) for cows supplemented with YC and YC+EHY compared with control. Although weekly treatment differences in milk were not statistically evaluated, milk yield for cows supplemented with YC and YC+EHY was consistently higher over the initial 11 wk of the experimental period compared with controls (Figure 1). Those supplemented with YC+EHY tended to exhibited higher starting milk yields (wk 2–4). Fat percentage was unaffected ($P > 0.05$) by treatment. Protein percentage was higher ($P < 0.01$) for cows supplemented with YC+EHY compared with control; YC was not different from either YC+EHY or control. Weekly protein profiles (Figure 2) illustrated that by wk 2 of experiment, cows supplemented with YC+EHY tended to have a consistently higher protein percentage than control cows. Lactose percentage was not affected ($P > 0.05$) by treatment.

Milk fat yields were higher ($P < 0.01$) for cows supplemented with YC and EHY+YC compared with control cows. Milk protein yields were higher ($P < 0.01$) for EHY+YC compared with control cows, with YC cows not different from either. Figure 3 illustrates that protein yields tended to be higher for cows supplemented with YC+EHY in wk 2 through 4; thereafter both YC and EHY+YC were similar and tended to be higher than control during the remainder of the trial period. Treatment did not affect MUN, with all treatments ranging from 11.1 to 11.4 mg/dL. Treatment did not affect BW or BCS (Table 4).

Health and Mastitis

Health disorders were not affected ($P > 0.05$) by treatment (Table 5). Somatic cell count during the 14-wk experimental period was lower ($P < 0.01$) for cows supplemented with YC+EHY compared with control and YC (Table 6). Figure 4 illustrates that the treatment effect on SCC appeared to be more pronounced during the second half of the trial period. During wk 1 through 7 of trial, no differences among treatments were observed; however, during wk 8 to 14, cows supplemented with YC+EHY had lower ($P < 0.01$) SCC compared with control and YC. New clinical cases of mastitis were numerically lower for cows supplemented with YC+EHY compared with control and YC. This difference was mainly exhibited during wk 8 to 14 of the trial.

DISCUSSION

Yeast Product Characterization

When interpreting data associated with yeast supplementation, confusion often exists regarding the diver-

Table 3. The effect of yeast culture and enzymatically hydrolyzed yeast on milk composition of lactating cows

	Treatment[1]				*P*-value
Item	Control	YC	YC+EHY	SEM	Treatment
Cows/pen[2]					
Pen 1	24	23	25		
Pen 2	23	23	23		
Milk yield, kg					
Milk	40.5[b]	41.9[a]	42.1[a]	0.7	0.01
3.5% FCM	41.6[b]	43.2[a]	43.4[a]	0.9	0.01
ECM	40.9[b]	42.6[a]	42.8[a]	0.8	0.01
Milk composition, %					
Fat	3.67	3.7	3.72	0.04	NS
Protein	2.91[b]	2.93[ab]	2.98[a]	0.01	0.01
Lactose	4.67	4.68	4.66	0.01	NS
MUN, mg/dL	11.1	11.4	11.2	0.13	NS
Milk component yield, kg					
Fat	1.48[b]	1.55[a]	1.56[a]	0.04	0.01
Protein	1.17[b]	1.21[ab]	1.24[a]	0.02	0.01

[a,b]Means within the same row with different superscripts differ ($P < 0.05$) by Tukey-Kramer test.

[1]Control = standard herd fresh cow diet; YC = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; YC+EHY = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

[2]Reasons for cow removal from trial: Control = pen1, 1 cow: mastitis, pen 2, 2 cows: injury and ketosis. YC = pen 1, 2 cows: foot rot (lameness) and mastitis, pen 2: injury, ketosis/displaced abomasum; YC+EHY = pen 2, 2 cows: ketosis and lameness.

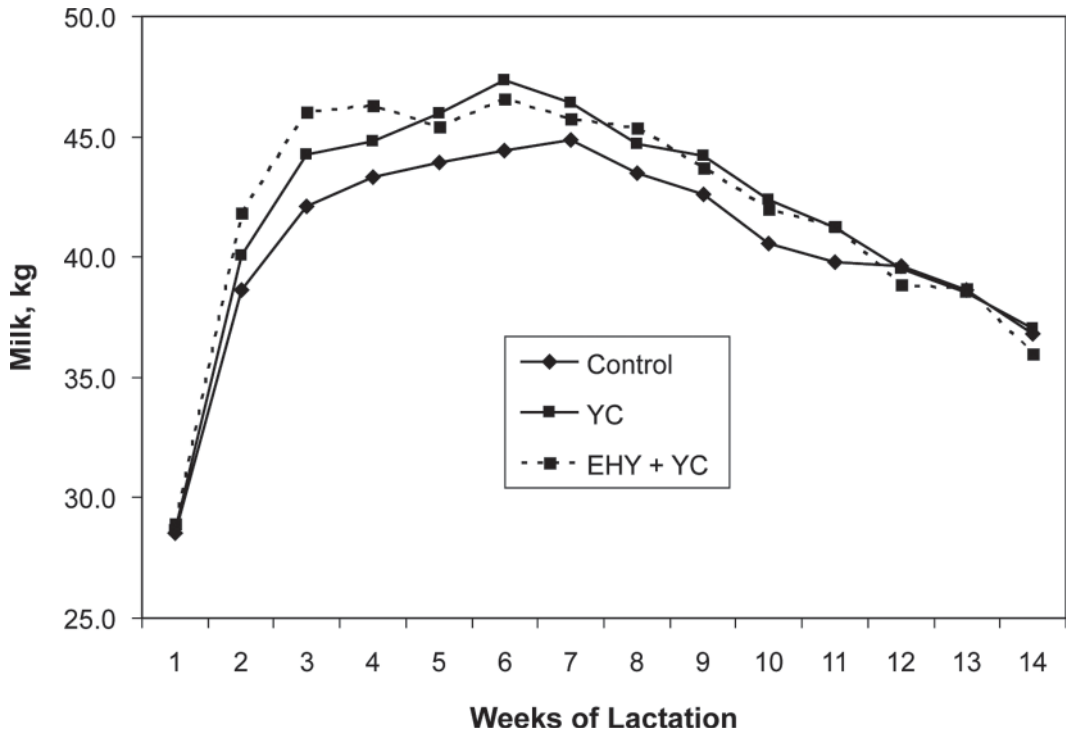

Figure 1. Mean weekly milk yield (data are weekly means by pen then converted to cow/d, SEM = 1.52). Control = standard herd fresh cow diet; yeast culture (YC) = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; and yeast culture/enzymatically hydrolyzed yeast (EHY+YC) = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

sity of products, their composition, processing effect on probable mode of action, and in the case of yeast cell wall, the active chemical moieties. The yeast culture used in this study was composed of dead cell walls (typically from strains of *Saccharomyces cerevisiae*), the medium on which yeast were grown, and a few and variable live yeast cells. This milieu is the active liquid ingredient, which is then dried onto a variable amount of carrier (usually a grain source), which typically dictates the amount of end product fed. The addition of enzymatically hydrolyzed yeast cell wall (EHY) and yeast cell metabolites, which contain the MOS and β-glucan components, is added to the liquid milieu of the YC and dried on a carrier. This differs significantly from "live cell" yeast, which is required to be viable to exert a direct effect in the rumen, usually associated with oxygen scavenging or reduction of ruminal redox potential (Marden et al., 2008). Several processes are required in the development of yeast products, which are critical to their activity and differentiation: yeast strain, yeast growth media, carrier, drying process, and cell wall fractionation technique (i.e., mechanical, chemical, enzymatic).

There is conflicting information associated with yeast cell wall composition, exposed moieties, and their potential activities. The yeast cell wall is composed of about 50% β-1,3 glucans, 10% β-1,6 glucans, and 40% mannoprotein (Lipke and Ovalle, 1998). Therefore, although mannose is an important high-affinity cell wall ligand, other molecules exist (*N*-acetyl galactosamine, D-galactosamine, D-glucosamine, D-glucose, and D-galactose) that may have unique binding potential (e.g., *N*-acetyl galactosamine with *Cryptosporidium parvum* (Hashim et al., 2006). In addition, the method of processing could dictate the degree and consistency of exposure associated with the various moieties. In the present study, yeast cell wall was prepared by enzymatic hydrolyzation. Enzymatic processing of yeast cell wall at optimal temperature, time, and pH yields a consistent exposure of binding sites compared with chemical or mechanical fractionation (Balasundaram and Harrison, 2006; Pitarch et al., 2008). Therefore, comparative study evaluation among trials in response to different YC or cell wall preparations requires clarification and greater definition to be meaningful.

Production Performance

Literature evaluation of the effects of YC on production performance is variable (Robinson and Garrett, 1999; Soder and Holden, 1999). Several factors have been suggested that influence the response of dairy

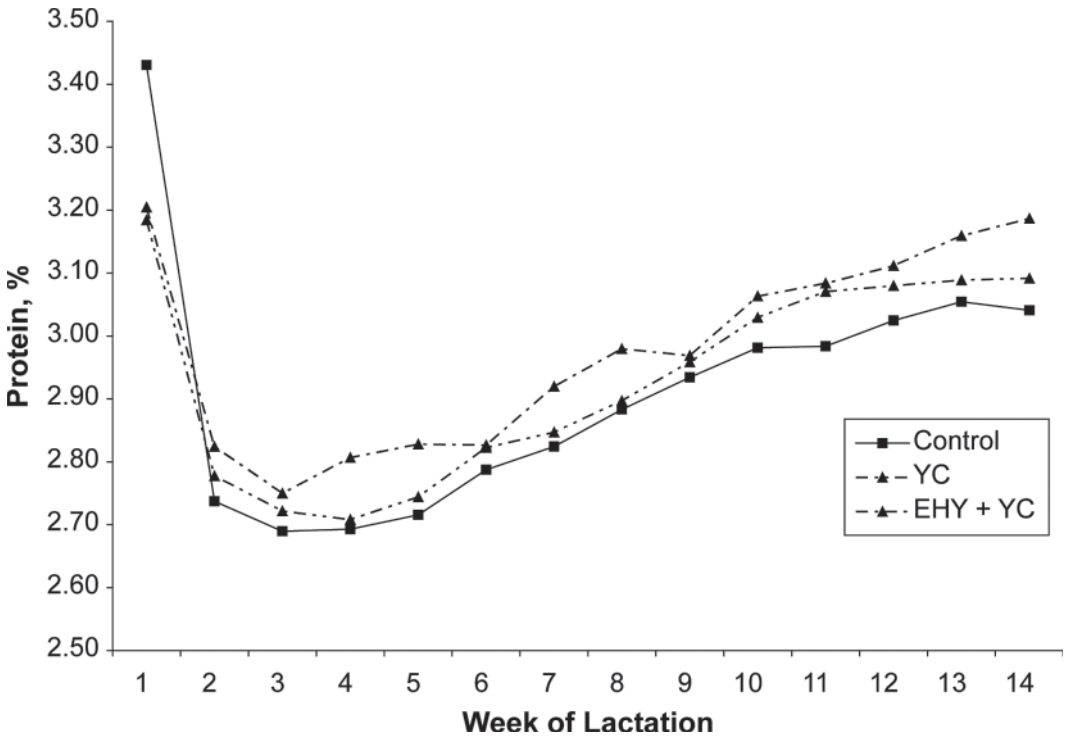

Figure 2. Mean weekly protein percentage (data are weekly means by pen then converted to cow/d, SEM = 0.032). Control = standard herd fresh cow diet; yeast culture (YC) = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; and yeast culture/enzymatically hydrolyzed yeast (EHY+YC) = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

cows to YC treatments, including stage of lactation, age, composition of the feed, and feeding strategy (Piva et al., 1993; Desnoyers et al., 2009). Milk production differences found in the present study are supported by findings in other studies and reviews (Shaver and Garrett, 1997; Nocek et al., 2003; Desnoyers et al., 2009) with mean responses typically from 0.5 to 1.0 kg. The lack of response to YC of fat percentage in the present study has been shown by others (Arambel and Kent, 1990), as has the lack of response for milk protein (Dann et al., 2000; Moallem et al., 2009); however, the increase in milk protein percentage associated with the addition of EHY has not been documented. Mode of action attributed to YC been shown to modify rumen function by stimulating fermentation (Robinson, 1997), increasing populations and growth rates of cellulolytic bacteria, and enhancing the initial digestion rate of forages. In continuous culture work with the YC used in the current study, Miller-Webster et al. (2002) demonstrated no effect on NDF digestion, but showed increased microbial N per kilogram of DM digested, and an increased protein concentration of microbes compared with other YC products. The increased quantity and quality of microbial protein delivered postruminally could aid in supporting more milk protein.

A few performance studies have been conducted associated with hydrolyzed yeast products. Calves supplemented with fructooligosaccharides or MOS did not show enhanced growth performance (Heinrichs et al., 2003; Hill et al., 2008, 2009). Davis et al. (2002) demonstrated improved ADG and feed efficiency for weaned piglets supplemented with MOS. Further justification for a performance response (increased milk protein) associated with EHY could be derived from modification to enteric microflora such that provisional nutrients are spared for host availability rather than bacterial utilization, thus more energy and amino acid substrate are available for protein synthesis, as described by Ferket (2002) in turkeys.

SCC and Mastitis

The addition of EHY to YC clearly affected SCC and clinical mastitis in this study. The concept of subclinical pathogenic challenges and their relation to MOS or β-glucan has not been extensively studied in mature dairy cattle. Franklin et al. (2005) supplemented dry cows with MOS and observed an enhancement of humoral immune response to rotavirus and a tendency for enhanced transfer of rotavirus antibodies to calves, thus

Table 4. The effect of yeast culture and enzymatically hydrolyzed yeast supplementation on BW and BCS at calving and 14 wk postpartum

	Treatment[1]				*P*-value
Item	Control	YC	YC+EHY	SEM	Treatment
Cows/pen					
Pen 1	24	23	25		
Pen 2	23	23	23		
BW, kg					
Initial	701	687	705	14	NS
Final	688	682	691	16	NS
Change	13	5	15		
BCS					
Initial	3.48	3.46	3.52	0.05	NS
Final	3.28	3.29	3.32	0.07	NS
Change	0.2	0.17	0.2		

[1]Control = standard herd fresh cow diet; YC = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; YC+EHY = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

supporting the contention of an immuno-enhancement process. Waller et al. (2003) infused β-1,3-glucan at drying off into the udders of cows infected with *Staphylococcus aureus* and showed no therapeutic effect on quarters with chronic subclinical *Staph. aureus* mastitis. However, the proportion of major histocompatibility complex (MHC class II) and milk lymphocytes tended to increase after β-glucan infusion, suggesting some stimulation of antigen-presenting ability.

The effect of EHY on SCC could be linked to a potential immune response. Activation of the animal's immune system via antigenic exposure releases an ar-

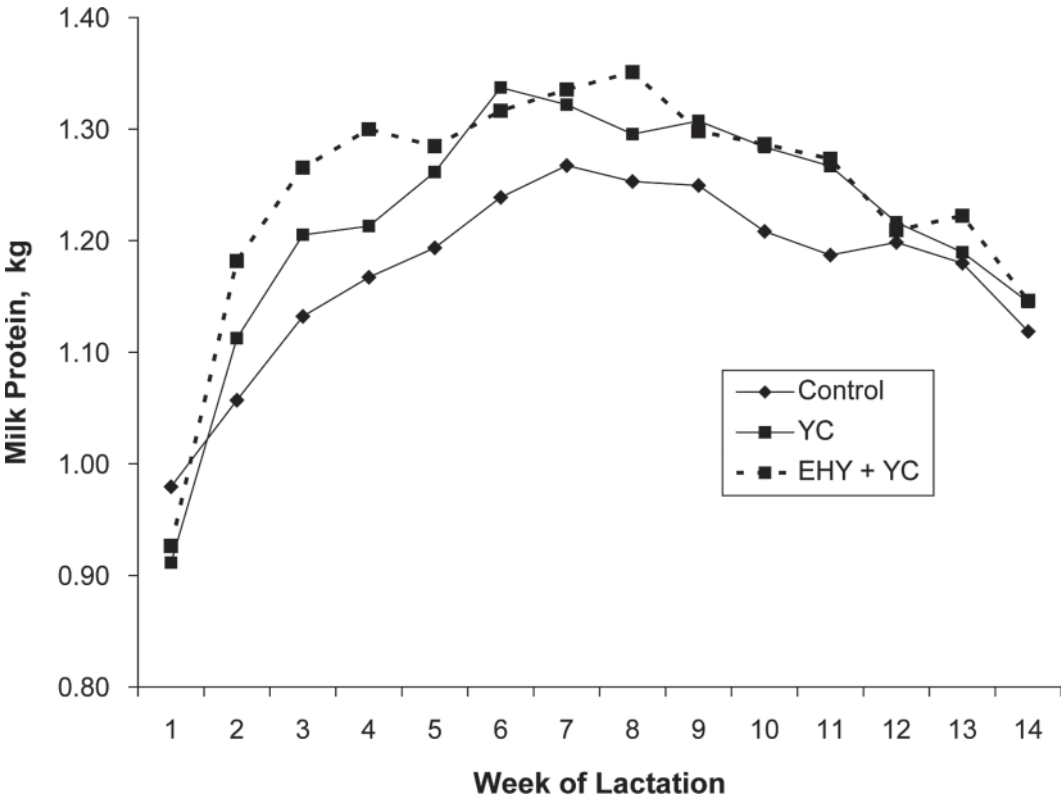

Figure 3. Mean weekly protein yield (data are weekly means by pen then converted to cow/d, SEM = 0.047). Control = standard herd fresh cow diet; yeast culture (YC) = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; and yeast culture/enzymatically hydrolyzed yeast (EHY+YC) = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

Table 5. The effect of yeast culture and enzymatically hydrolyzed yeast supplementation on health disorders

	Treatment[1]		
Item	Control	YC	YC+EHY
Cows/pen			
Pen 1	24	23	25
Pen 2	23	23	23
Incidence, % (no. affected)			
Twins	2.1 (1)	6.5 (3)	4.2 (2)
Retained placenta	4.3 (2)	6.5 (3)	6.3 (3)
Metritis	10.6 (5)	4.3 (2)	10.4 (5)
Ketosis	8.5 (4)	8.7 (4)	6.3 (3)
Displaced abomasum	4.3 (2)	6.5 (3)	4.2 (2)

[1]Control = standard herd fresh cow diet; YC = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; YC+EHY = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

ray of cytokines that initiates a cascade of metabolic events, including elevated body temperature, metabolic rate, gluconeogenesis, glucose oxidation, hepatic protein synthesis (Long, 1977; Baumann et al., 1987; Klasing, 1988), with a shift in hormone balance causing a reduction of circulating anabolic hormones (growth hormone, prolactin; van Deuren et al., 1992; Johnson and von Borell, 1994) and a concomitant increase in catabolic hormones (glucocorticoids; Woloski et al., 1985). This immune system-induced shift of endocrine status causes depression in intake, feed efficiency, and tissue composition in growing chicks and pigs (Stahly et al., 1995; Williams et al., 1997). Sauber et al. (1999) demonstrated that antigen exposure (LPS of *Escherichia coli*) to lactating sows resulted in a greater level of chronic immune system activation, feed intake depression, and reduced milk and milk energy in sows. Shuster et al. (1991) demonstrated that when cows received an intramammary infusion of LPS, milk and milk protein yield were reduced without mammary inflammation (indicative of mammary infection). These findings suggest that a lack of lactation performance was associated with a physiological change causing an escape of milk and components through increased permeability of the blood–milk barrier.

Another potential effect of dietary YC+EHY supplementation is the presentation of β-glucan to the γ-δ T cells of the intestine. Besides the gut epithelial cells, γ-δ T cells are among the first populations of cells to come into contact with pathogens presented via digesta in the intestine (Jutila et al., 2008). β-Glucan is now recognized as having an important pathogen-associated molecular pattern (PAMP), which primes this class of T cells, leading to increased proliferation and responsiveness to antigen or cytokines (Hedges et al., 2007). Bovine γ-δ T cells have been shown to respond to several common pathogens, including *Mycobacterium* spp. (Rhodes et al., 2001), *Cryptosporidium parvum* (Abra-

Table 6. The effect of yeast culture and enzymatically hydrolyzed yeast supplementation on SCC and clinical mastitis

	Treatment[1]				*P*-value
Item	Control	YC	YC+EHY	SEM	Treatment
Cows/pen					
Pen 1	24	23	25		
Pen 2	23	23	23		
SCC, × 1,000 cells/mL					
1 to 14 wk postpartum	241[a]	258[a]	178[b]	17	0.01
1 to 7 wk postpartum	180	209	181	16	NS
8 to 14 wk postpartum	303[a]	314[a]	177[b]	19	0.01
New clinical mastitis cases					
1 to 14 wk postpartum	12	10	5		
1 to 7 wk postpartum	2	3	2		
8 to 14 wk postpartum	10	7	3		

[a,b]Means within the same row with different superscripts differ ($P < 0.05$) by Tukey-Kramer test.

[1]Control = standard herd fresh cow diet; YC = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; YC+EHY = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

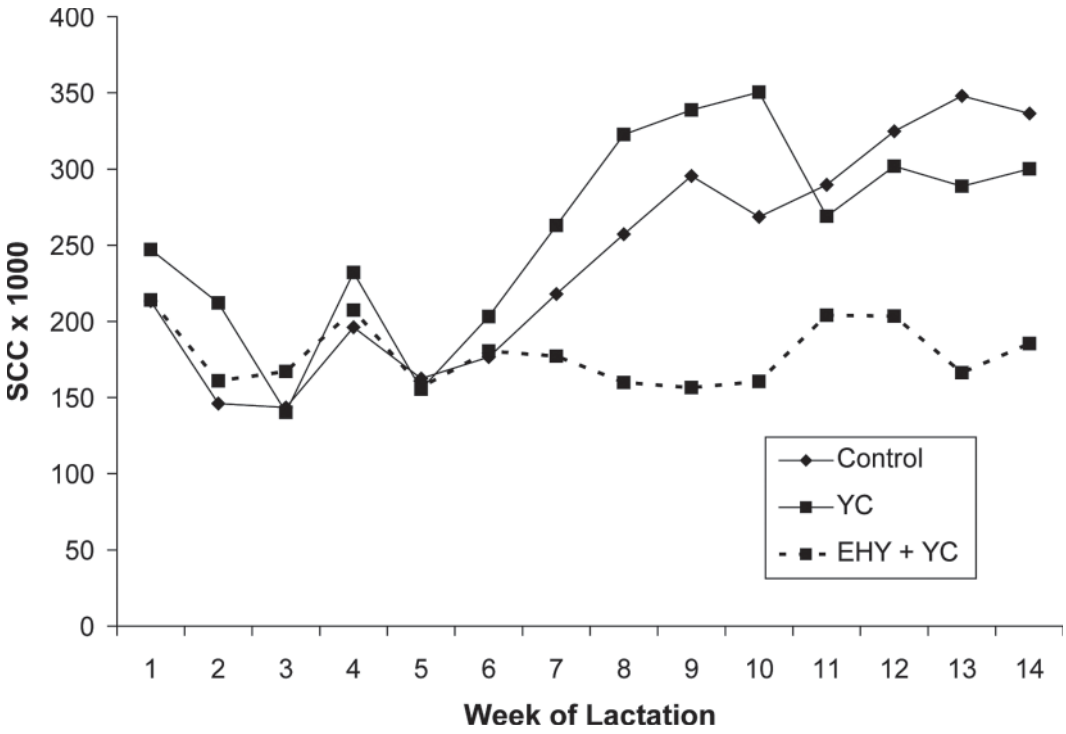

Figure 4. Mean weekly SCC (data are weekly means by pen then converted to cow/d, SEM = 25.6). Control = standard herd fresh cow diet; yeast culture (YC) = same as control, but with the inclusion of A-Max Yeast Concentrate (Vi-COR, Mason, IA) at 56 g/cow per day; and yeast culture/enzymatically hydrolyzed yeast (EHY+YC) = same as control, but with the inclusion of Celmanax (Vi-COR) at 28 g/cow per day.

hamsen, 1998), *Staphylococcus* spp. (Fikri et al., 2001), and *Salmonella enterica* (Hedges et al., 2007), resulting in enhanced activity of macrophages and neutrophils (Born et al., 1999).

Mounting an immune response to infection can be energetically expensive (Demas, 2004), thus prolonged negative energy balance at transition could affect immune competence (Waldron et al., 2003; Goff, 2006) and predispose cows to infectious disease after calving. Somatic cell count is a commonly used index of milk quality and a useful indicator to increase awareness of subclinical mastitis and its effect on production (Santos et al., 2004). The relation between SCC, mastitis, and EHY was identified in a study by Proudfoot et al. (2009), where cows supplemented with the EHY used in the present study experienced a reduction in subclinical mastitis and number of new clinical cases of mastitis. These authors reported elevated levels of IL-8, used to confirm the presence of an infection.

It could be speculated that the following processes were affecting the response to EHY in the present study: enteric nutrient sparing and a subclinical immune response (either promotion of humoral immunity or prevention of a hyperimmune response); however, the degree of this intervention is not clearly known. This poses interesting avenues of research associated with immuno-competence, prebiotics, and enhanced performance.

CONCLUSIONS

Cows supplemented with YC and YC+EHY produced more milk, FCM, and ECM than nonsupplemented cows. Milk protein percentage was elevated for cows supplemented with YC+EHY compared with control cows. Milk fat yield was higher for cows supplemented with YC and YC+EHY compared with control cows, whereas protein yields were higher for YC+EHY-supplemented cows compared with control cows. Somatic cell count was reduced for cows supplemented with YC+EHY; however, the response was associated more with wk 8 to 14 than wk 1 to 7 postpartum. Supplementation of early lactation cows with YC improved production performance, and further performance and mammary gland health benefits were achieved when cows were additionally supplemented with EHY.

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